SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA), formed by Reorganization Plan No. 1 of 1977, is responsible, under Executive Order 12046, for managing the radio frequency spectrum used and/or allocated to the U.S. Federal Government and is in charge of formulation of telecommunication policy. In addition, the telecommunications policy concerning the promotion of efficiency and economy of Government operations states that, "...the basic guide to follow in the normal assignment of radio frequencies for transmission purposes is the avoidance of harmful interference..." In carrying out its responsibility and to ensure the compatibility in frequency sharing between the satellites and the systems in the Fixed Service, the NTIA has undertaken the spectrum resource assessment of power flux-density (pfd) limits in the 2025-2300 MHz frequency range. This study determines limits to protect systems in the Fixed and Mobile Services from interference from satellites in space services without placing undue burden on the design of these satellites. This report provides a technical base for calculated limits that may be recommended for inclusion in the NTIA Manual for future use in such functions as frequency sharing and granting spectrum support to satellites in the 2025-2300 MHz frequency range.

PRELIMINARY DISCUSSIONS

In an earlier report (Farrar, 1982) the origin of the pfd limits and two recent analytical models used in the derivation of these limits were discussed. A computer model, developed by the Bell Telephone Laboratories (BTL) and another by the Systematics General Corporation (SGC) were used in the analysis section of that report. Included in the report were a discussion of the algorithms and the assumptions used in the development of the two analytical models. The computer model developed by the BTL was for evaluation of pfd limits for satellites in geostationary orbit and will be referred to as geostationary model (GM) in this report. The SGC computer model was developed to determine the pfd limits for low orbit satellites and will be referred to as non-geostationary model (NGM) in this report. Farrar (1983) pointed out that modifications to these two computer programs were necessary in order to determine the pfd limits for the 2025-2300 MHz frequency range. The following is a summary of these modifications described in Part I of Farrar (1983).

1. The receiver transfer function used in both GM and NGM programs should be modified to take into account the technical characteristics of the equipment in the 2025-2300 MHz frequency range. A qualitative analysis conducted in Part I indicated that the characteristic of the equipment presently used or planned in this frequency range may have a serious effect on the relationship for the transfer function used in the models.

2. Long-term fading effects should be incorporated in the GM computer algorithm in order to determine satellite interference noise power into a radio-relay as a function of percentage of a month.

3. The effect of potential interference to radio-relay receivers from non-geostationary satellites in multiple orbits should be determined by modifying the NGM computer program.

4. Fading data measured in the United States should be incorporated in the NGM program. The current NGM program makes use of fading data measured in Germany.

5. In the calculation of pfd limits considerations should be given to the combined effects of interference from satellites both in geostationary and non-geostationary orbits for special cases when satellites in low orbits have low inclination angles.

Systems in the Mobile Service were assumed to be operationally less susceptible to interference from satellites than the systems in the Fixed Service. However, systems in Aeronautical Telemetry Mobile Stations used in the flight testing of manned or unmanned aircraft, missiles, or major components thereof, were left for consideration in this follow-up analysis. Both GM and NGM computer models were developed for calculating the power flux densities which limit the interference from satellites to the systems in Fixed Service which share the same frequency range with satellites and use FDM/FM modulation and line-of-sight transmission. There are a large number of digital systems in the Fixed Service in the 2025-2300 MHz frequency range. An analysis was found necessary in this effort to determine if the pfd limits designed to protect the terrestrial analog systems were sufficient to provide compatible operation between terrestrial digital systems and spacecraft operating in the 2025-2300 MHz frequency range.

This report treats the modifications listed above in the computer models and the problems associated with the terrestrial digital systems using LOS techniques for the evaluation of the pfd limits in the desired frequency range. A review of the pfd limits given in the ITU and adopted in the NTIA Manual (1983) is also included.

OBJECTIVES

The overall objective of this task was to assess the pfd limits from satellites at the surface of the Earth in the 2025-2300 MHz frequency range. The following specific objectives were identified for this effort.

1. Determine pfd limits applicable to the United States for the satellites in geostationary and non-geostationary orbits that will not jeopardize the operations of the systems in the Fixed Service using line-of-sight transmission in the 2025-2300 MHz frequency range.

2. Review the existing pfd limits for space stations in the NTIA Manual, determine if those limits should be modified, and recommend the appropriate modification to these limits.

3. Review the power flux limit for systems using tropospheric transmission in the 2025-2300 MHz frequency range as given in the NTIA Manual.

4. Identify the problem areas which need more detailed analysis.

APPROACH

The interactions between services involved in the determination of pfd limits for the 2025-2300 MHz frequency range were analyzed and the existing interference criteria used in the calculation of these limits were reviewed. Information on the characteristics of space and terrestrial systems operating in this frequency range and given in Part 1 of this report were up-dated to determine the characteristics of typical systems in this frequency range.

Modification of the two computer models (GM and NGM) was necessary before the proper pfd limits for the desired frequency range could be determined. The following approach was used in carrying out the modifications of the GM and NGM computer programs.

The GM computer program in its original form did not consider fading of RF signals and the fading data used in the original design of the NGM program were data taken in Europe at 4 GHz. The fading data statistics for radio frequency (RF) signals measured by the Bell Telephone Laboratories (BTL) at different areas of the United States were incorporated in both the GM and NGM programs.

1. The NGM program was designed to carry out the computation of pfd limits for satellites in one orbit at a time. The program was modified to take into account the effects of satellites in different orbits in the computation of the pfd limits.

2. Combined effects of interference from satellites in both geostationary and non-geostationary orbits in the calculation of pfd limits were considered.

3. The expression for the radio-relay receiver transfer function used in both GM and NGM program was modified to take into account the characteristics of the equipment used in the 2025-2300 MHz frequency range. A new transfer function for this frequency range was derived and incorporated in the computer programs.

4. The assumption of on-tune interference from a satellite to all the receivers in a trendline was used originally in both GM and NGM programs. This assumption was not applicable to the terrestrial systems in the desired frequency range. Modifications to the programs were made to determine the pfd limits for this frequency range based on different applicable frequency-engineering-plans for a trendline.

The approach outlined above was for the determination of pfd limits considering the characteristics of FDM/FM analog radio receivers in the 2025-2300 MHz frequency range. The approach used in evaluating the adequacy of these limits for the digital radio receivers is as follows. Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Amplitude Shift Keying (ASK) were assumed to be representative types of digital modulation for the analysis. Three computer programs were prepared to calculate probability of bit-error-rate (Pe) for the three different kinds of modulation in the presence of

Gaussian noise. Using these computer programs plots of Pe vs Signal-to-Noise (S/N) ratio were obtained for the three types of modulation. The curves in these plots were used to assess the effect of analog pfd limits on trendlines using digital systems.

The effect of each modification listed above on the determination of pfd limits was determined separately. The final values of pfd limits found as a result of the analysis given here include the contributions made by all the modifications. The pfd limits for the 2025-2300 MHz frequency range were calculated after the modifications were incorporated in the computer models.

The historical basis used in establishing existing level of power density from satellites for systems using tropospheric propagation was reviewed in order to provide insight for its application. In addition, the non-compliance of the U.S. Satellites with the ITU limit for systems using troposhperic propagation was reviewed.